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Track Time and Monetary Costs of Transportation as a Comprehensive Performance Measure: Development and Application of Transportation Cost Index

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Tracking time and monetary costs of transportation as an accessibility measure: Development and application of Transportation Cost Index

Liming Wang, Portland State University

In Collaboration with

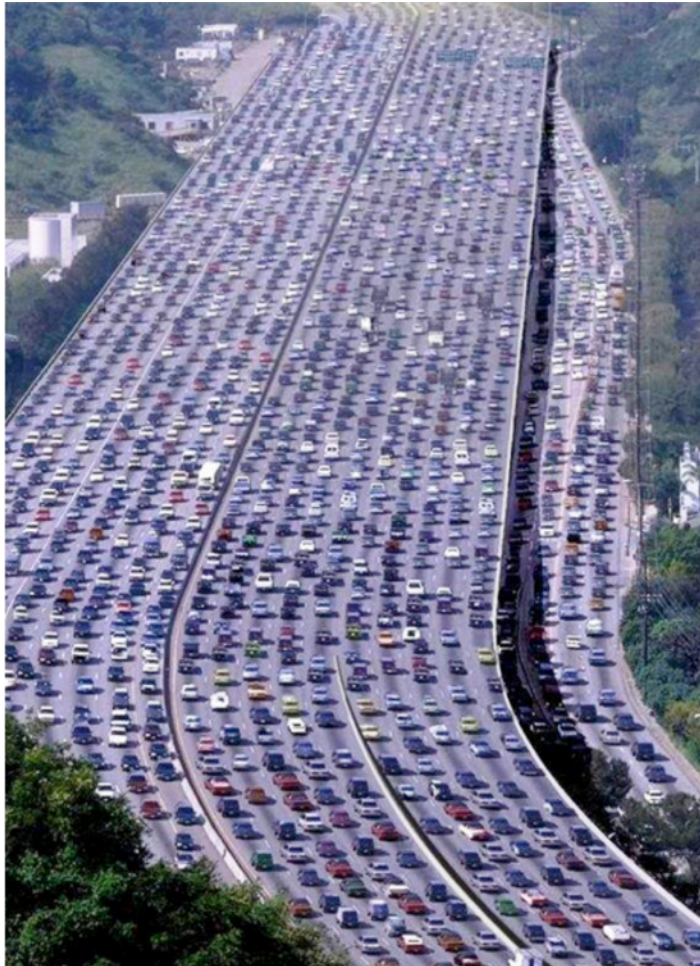
Jenny Liu, Huajie Yang, Wei Shi (PSU)

Bud Reiff (Metro), Brian Gregor (Oregon System Analytics)

Outline

- Why we need yet another performance measure (YAPM)?
- Transportation Cost Index: the idea and implementations
- Applications and Demonstration
- Conclusions

Performance Measures: Mobility vs Accessibility



Credit: Paul Waddell

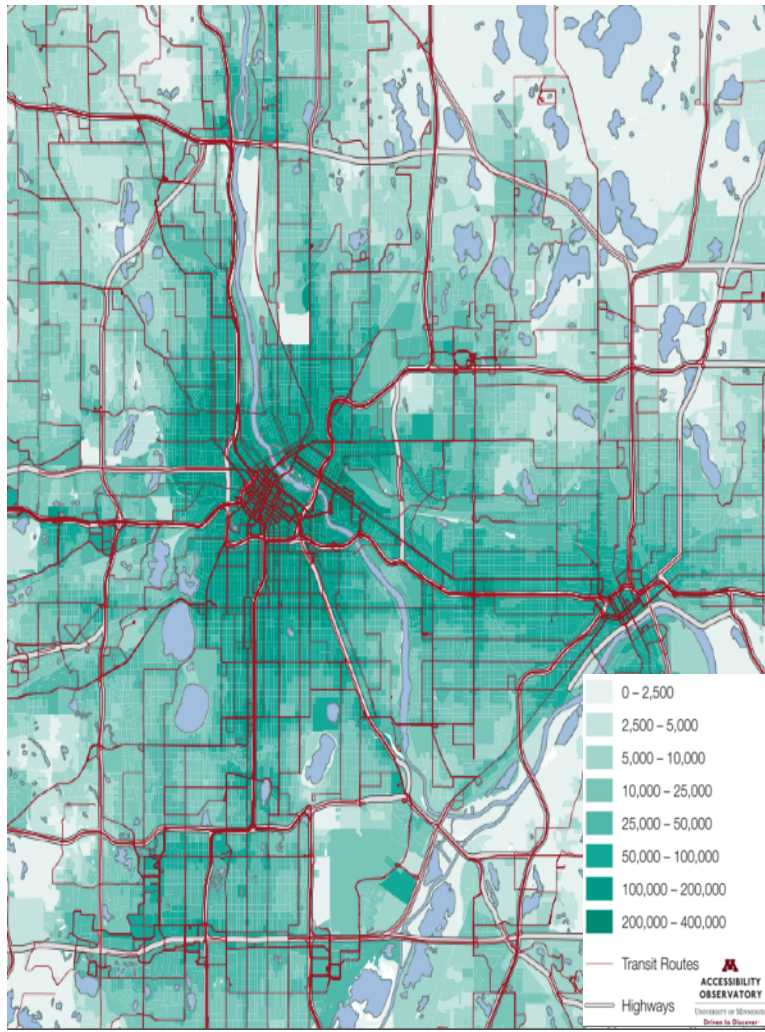
Need for Accessibility Measures

- As a supplement/replacement of traffic-centric measures: LOS, travel delays/congestion
- MAP-21 emphasizes use of performance measures in transportation planning & operation
- State legislations: Oregon Job and Transportation Act (OJTA)

Existing Accessibility Measures

- Handy and Niemeier, 1997
- Geurs and van Wee, 2004
- NCHRP Report 446, 618, 694, 708 ...

Market Potential Measures



Employment accessible within 30 minutes by public transit during a.m. peak

- Easy to interpret/understand
- Opportunities, mode, time-of-day and time budget specific

Source: University of Minnesota, Accessibility Observatory

Utility-based Measures

$$E(CS) = \ln \left(\sum_{m'} \exp(U_{m'kj}) \right) + C$$

Logsum as an accessibility measure

- An Elegant, composite measure for all modes; possible to derive net user benefit between scenarios
- Hard to interpret by itself; unable to compare across regions/times (benchmarking)

Generalized Costs Indicator

Table 4
Generalised costs indicator, for private car, 2007 (2000=100) by type of trip.

Location:	Randstad	107
	Outside Randstad	105
Time of day	Rush hour	109
	Outside rush hour	105
Trip purpose	Business	102
	Commuter	110
	Other	106
Distance (km)	Up to 15	105
	15 to 30	110
	30 to 50	108
	More than 50	104

Per distance generalized costs for motorized trips

- Easy to interpret/understand; able to monitor trends and compare scenarios
- ignores land use system; mode, time-of-day specific

Source: Koopmans, et al, 2013

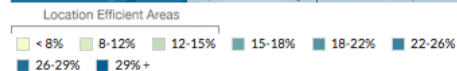
H+T® Affordability Index

Municipality: Portland, OR

Traditional measures of housing affordability ignore transportation costs. Typically a household's second-largest expenditure, transportation costs are largely a function of the characteristics of the neighborhood in which a household chooses to live. [Location Matters](#). Compact and dynamic neighborhoods with walkable streets and high access to jobs, transit, and a wide variety of businesses are more efficient, affordable, and sustainable.

The statistics below are modeled for the Regional Typical Household. Income: \$58,110 Commuters: 1.12 Household Size: 2.55 (Portland-Vancouver-Hillsboro, OR-WA)

Map of Transportation Costs % Income



Location Efficiency Metrics

Places that are compact, close to jobs and services, with a variety of transportation choices, allow people to spend less time, energy, and money on transportation.

6%

Percent of location efficient neighborhoods

Neighborhood Characteristic Scores (1-10)

As compared to neighborhoods in all 955 U.S. regions in the Index

Job
Access
6.9

High access to a variety
of jobs

Transit
Access
8

Very good access to
public transportation

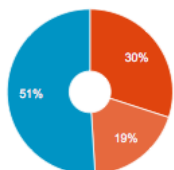
Compact
Neighborhood
5.7

Moderate density and
walkable

Average Housing + Transportation Costs % Income

Factoring in both housing and transportation costs provides a more comprehensive way of thinking about the cost of housing and true affordability.

● Housing
● Transportation
● Remaining
Income



Transportation Costs

In dispersed areas, people need to own more vehicles and rely upon driving them farther distances which also drives up the cost of living.



\$10,959

Annual Transportation Costs



1.53

Autos Per Household



17,121

Average Household VMT

- Tracks out-of-pocket monetary costs of transportation and adds them to housing costs as a location efficiency measure;
 - Ignores time costs; not track the performance of transportation system except for Auto/Transit mode split and VMT.
- Source: Center for Neighborhood Technology (CNT)

Wish List for YAPM

- A comprehensive measure able to present an overall picture of transportation and land use;
- Fill gaps in policy areas not adequately covered by existing performance measures, such as the equity and compatibility aspects (Reiff and Gregor, 2005)
- Easy to interpret/understand;
- Applicable to use cases ranging from prioritization, scenario evaluation/comparison, to benchmarking and standard;

Applicability of Performance Measures

Application	Prioritization	Comparison	Long-term Benchmark	Near-term Standard or Threshold
Transportation System Planning / Subarea Plans / Multi-jurisdictional Corridor Planning		TCI		
Project / Corridor Planning				
Plan Amendments / Zone changes subject to TPR				
Development Review				

Selection Criteria:

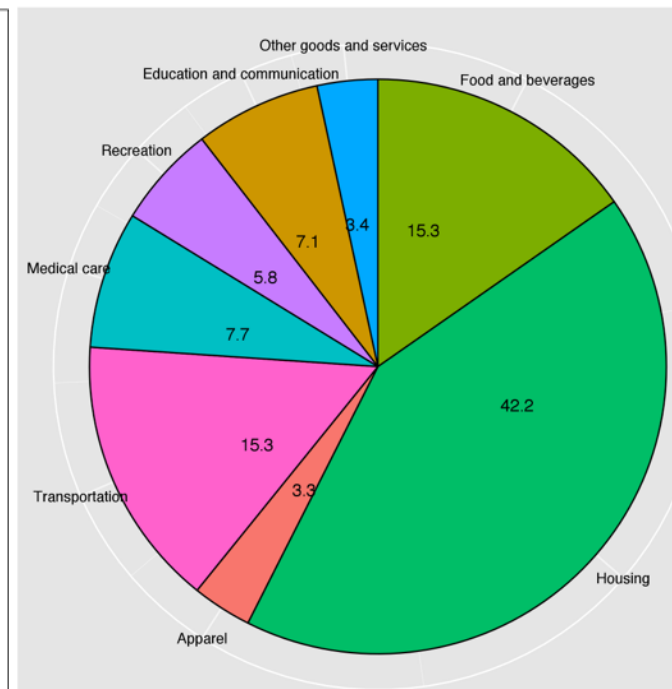
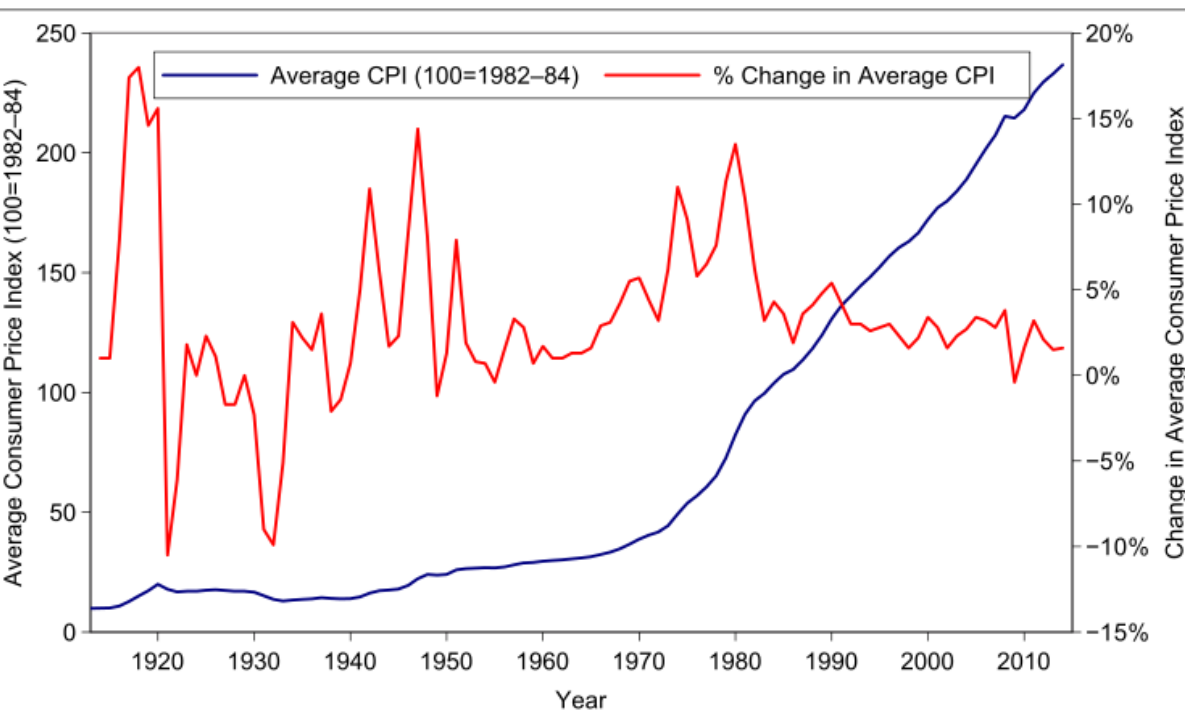
- Easy to apply
- Objective quantitative measure
- Good data availability
- Easy to understand

Source: Kittleson & Associates, Washington County Multimodal Performance Measures and Standards

TCl: the idea and implementations

Consumer Price Index (CPI)

United States Consumer Price Index 1913–2014



From CPI to Transportation Cost Index (TCI)

Measures changes in the “price level” of a market basket of trips/destinations meeting households’ daily needs:

1. Identify a basket of trips/destinations based on pre-defined groups (e.g. trip purpose categories);
2. Track the time and monetary costs of accessing trips/destinations in the basket.

Transportation Cost Index (TCI)

- Comprehensive measure of transportation and land use;
- Able to serve as a performance measure for policy areas including equity, transportation and land use compatibility and balance;
- Easy to interpret/understand;
- Based on widely available data sources, possible for all types of applications, esp. benchmarking and scenario evaluation/ comparison

Implementation A: Travel Survey-based Method

Relies primarily on input from household activity survey, e.g. Oregon Travel & Activity Survey (OTAS)

1. Construct travel baskets based on activity diaries or a sample of trips/tours that are representative of regional travel pattern, potentially by trip purpose, household size, income group and geography;
2. Track the time and monetary costs of making these trips/tours.

Suitable for prioritization and benchmarking applications.

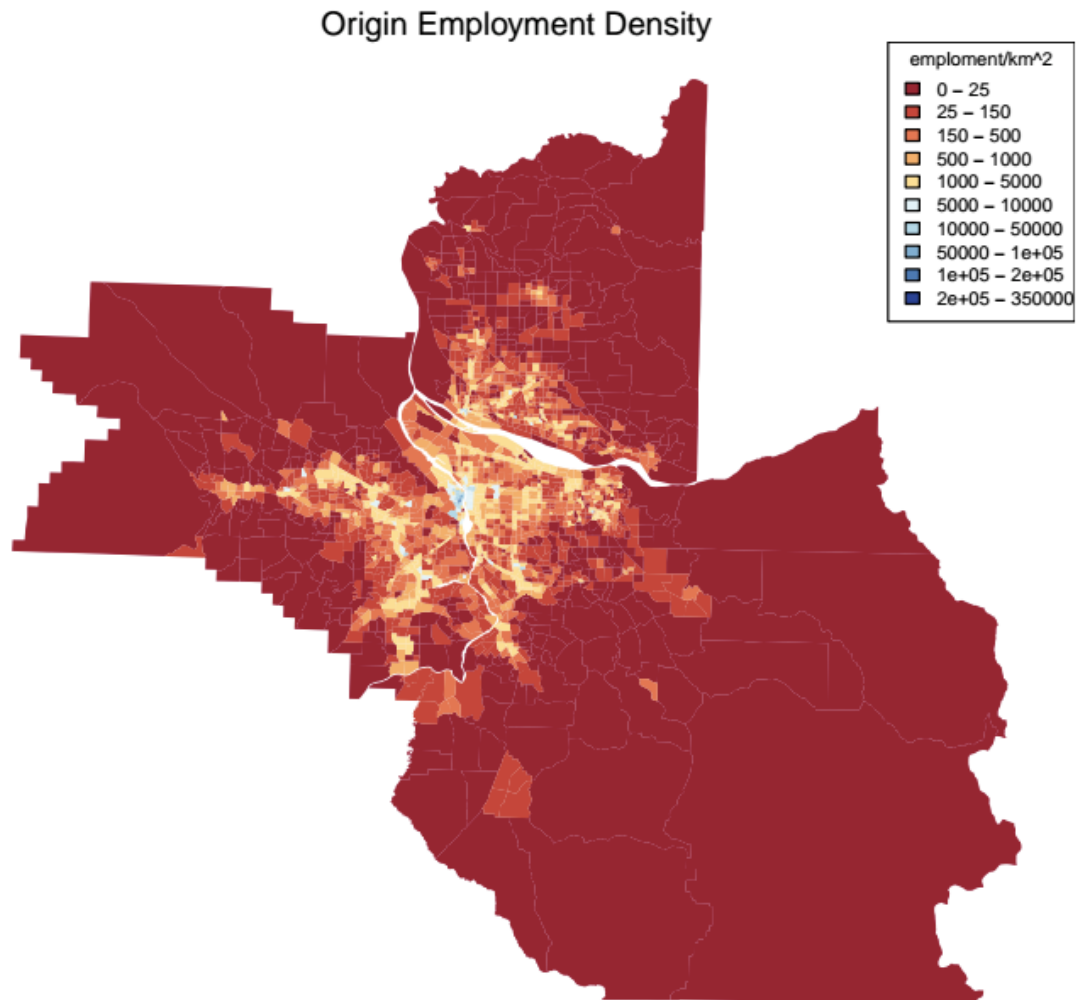
Implementation B: TDM-based Method

Relies on inputs from travel demand model

- Data readily available for regions w/ TDM;
- Theoretically can calculate the transportation cost for every income group and for every TAZ;

Suitable for scenario evaluation/comparison.

Implementation B: TDM-based Method



Calculate Travel Costs: Cost Estimate by Mode

$$C = C_0 + k \cdot TD + w \cdot TT$$

C_0 - Constant

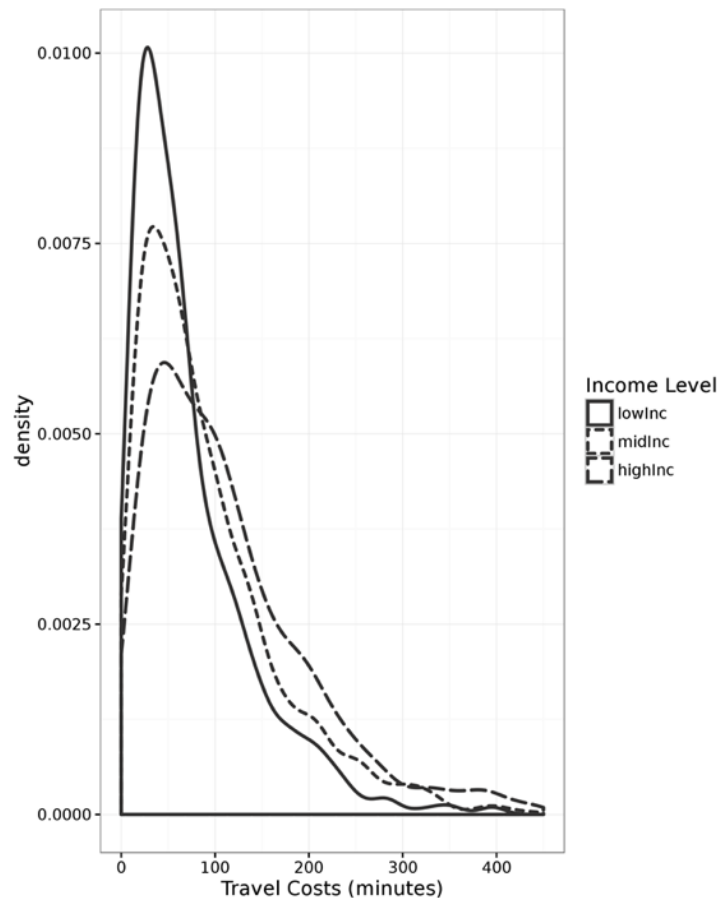
$k \cdot TD$ - Monetary costs (Fuel and tire costs, Ownership costs, insurance, etc) of travel

$w \cdot TT$ - Time costs of travel

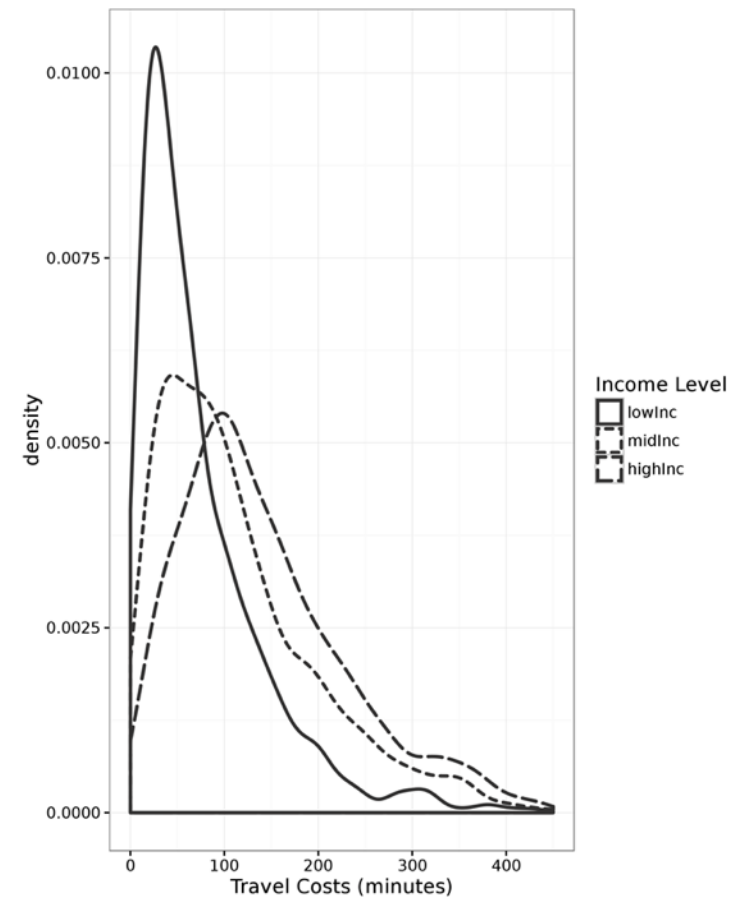
Applications and Demonstration

Generalized Costs by Household Income Level (Portland)

1994

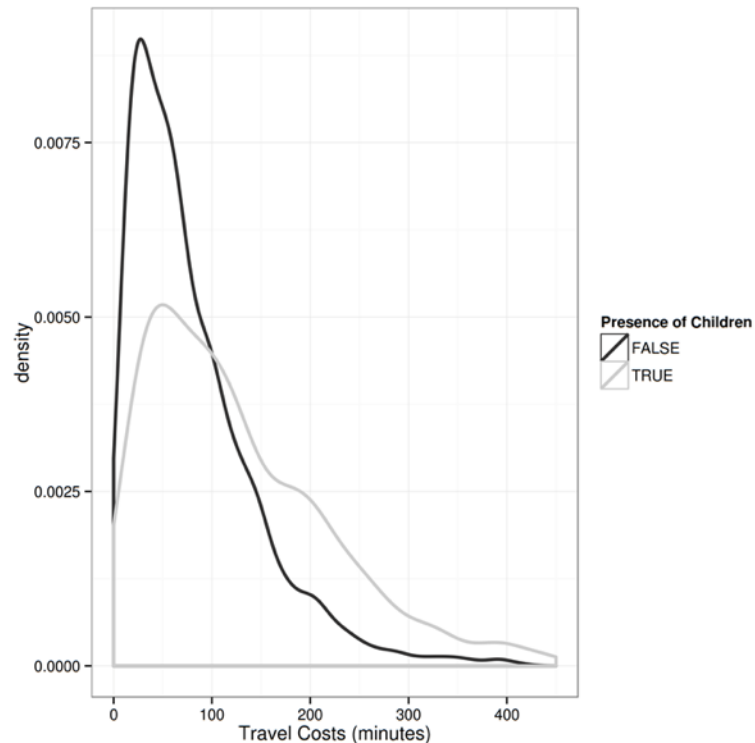


2011

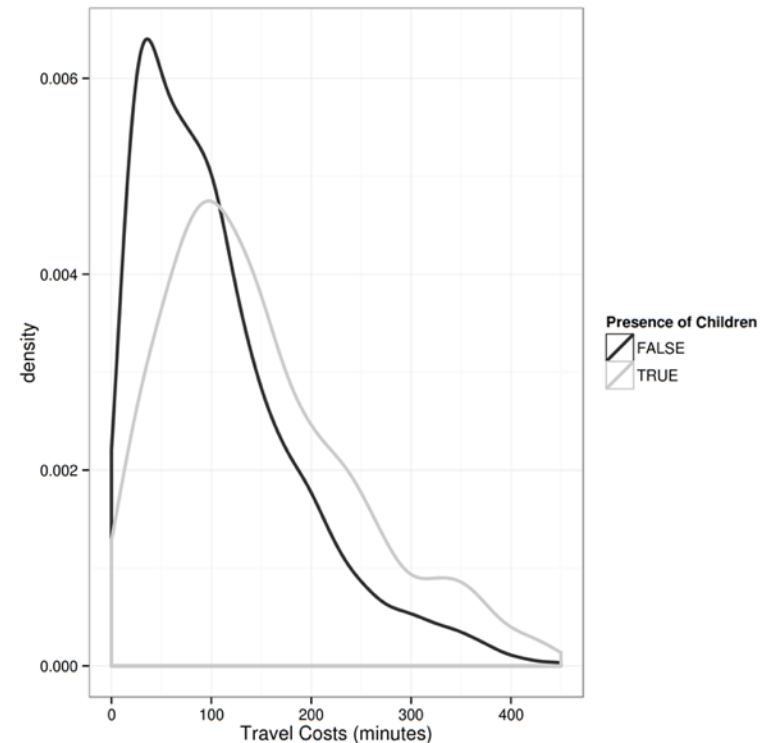


Generalized Costs by Presence of Children (Portland)

1994

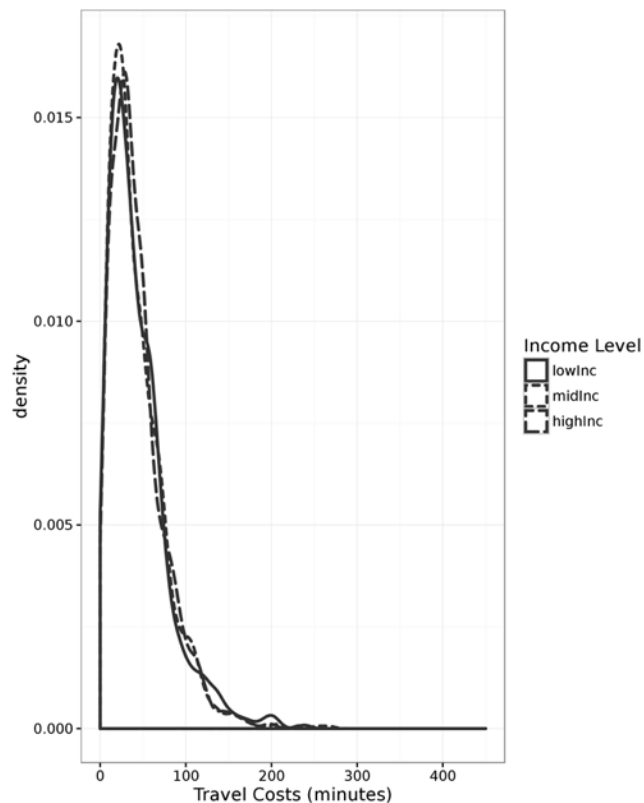


2011

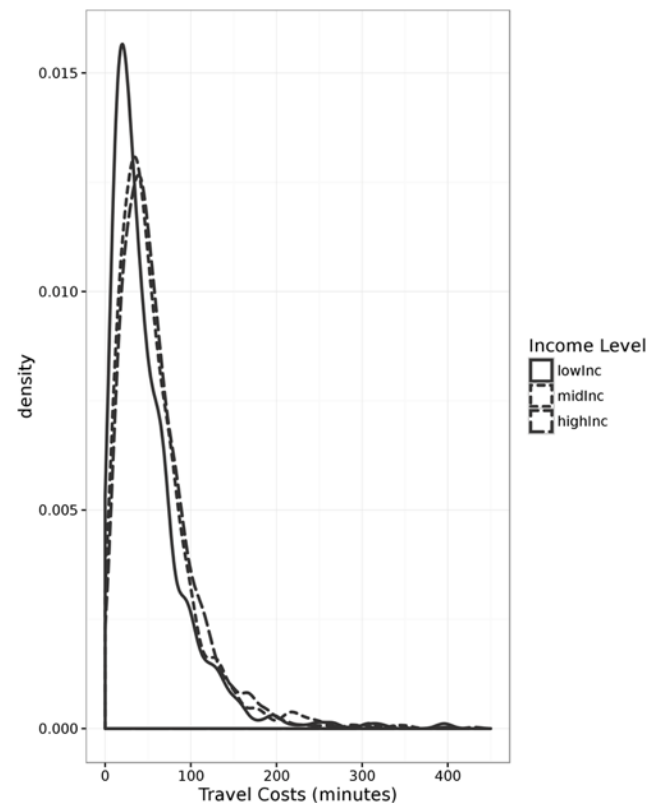


Per Person Generalized Costs by Household Income (Portland)

1994

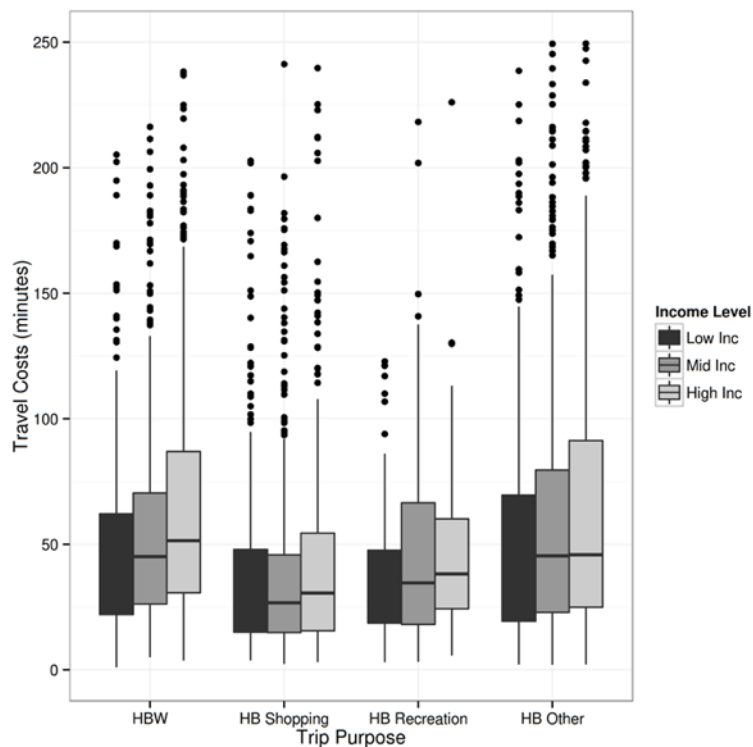


2011

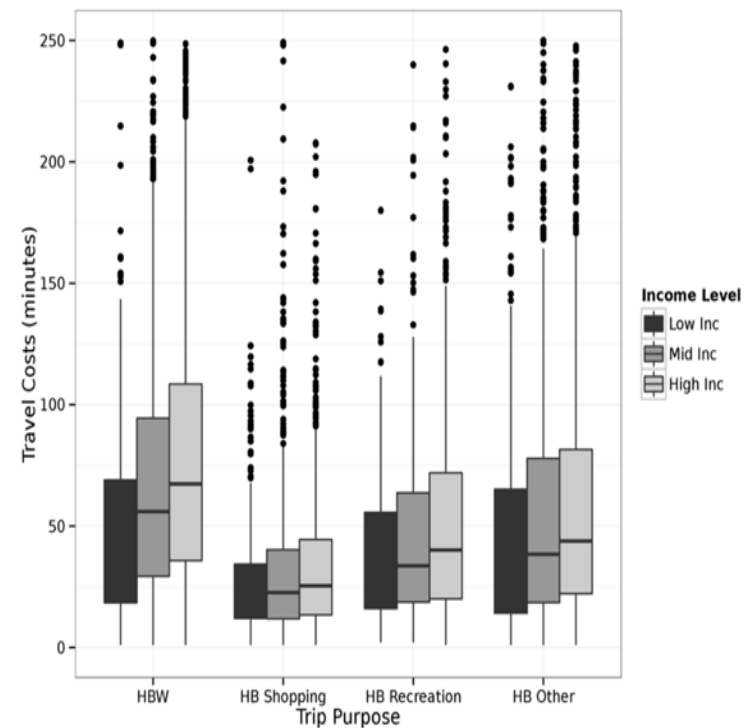


Generalized Costs by Purpose and Income Level (Portland)

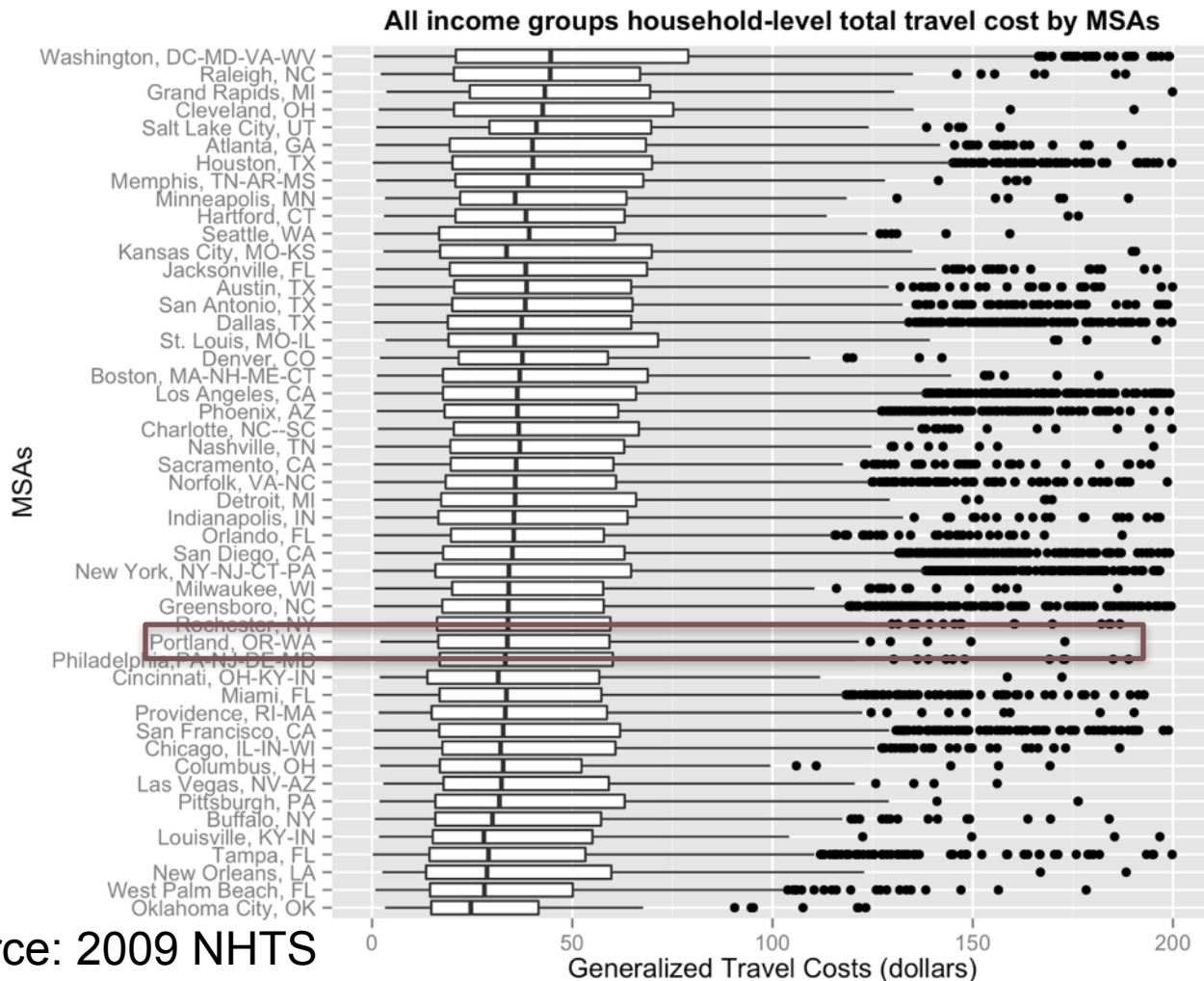
1994



2011

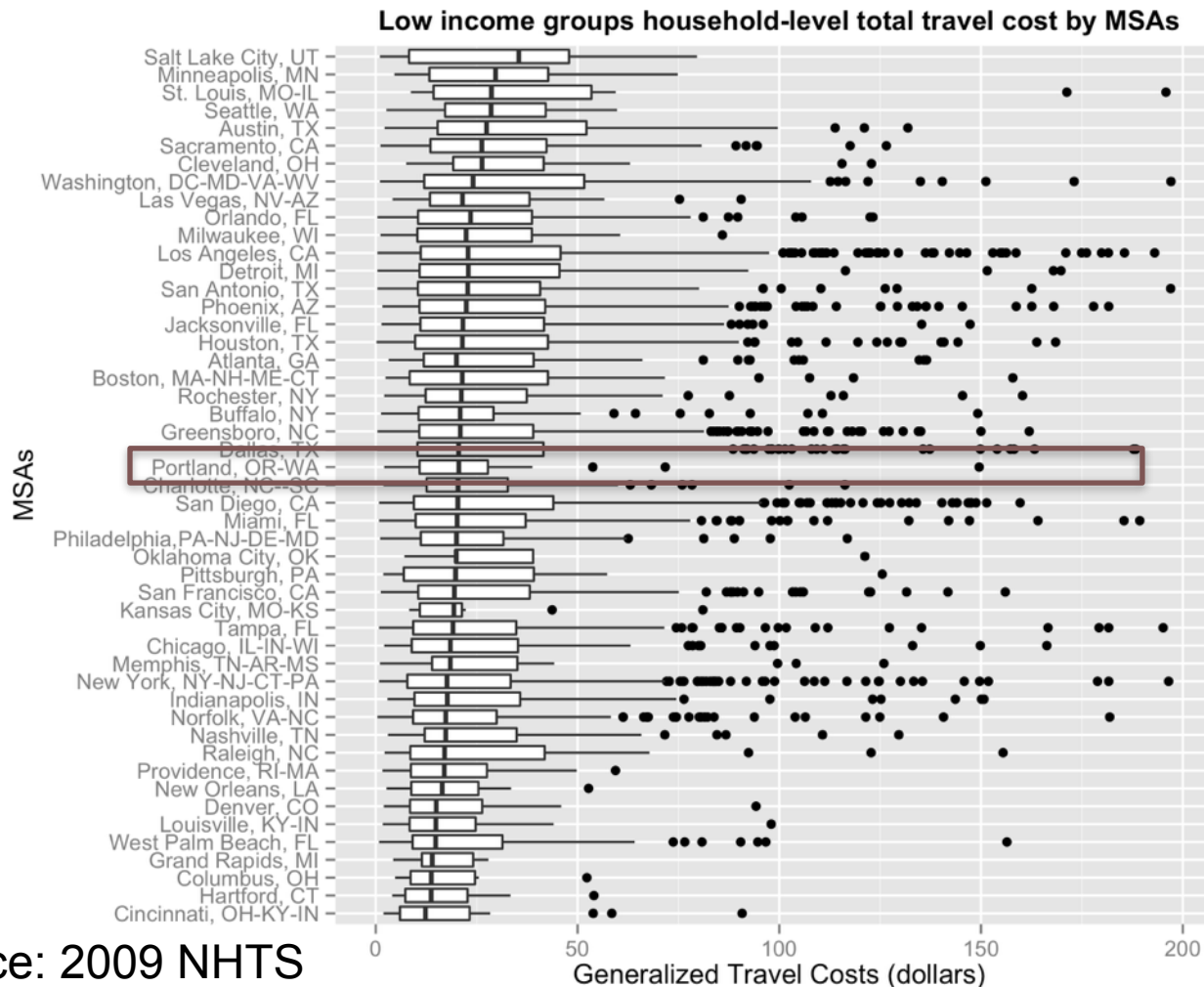


Transportation Costs by MSA (All households)

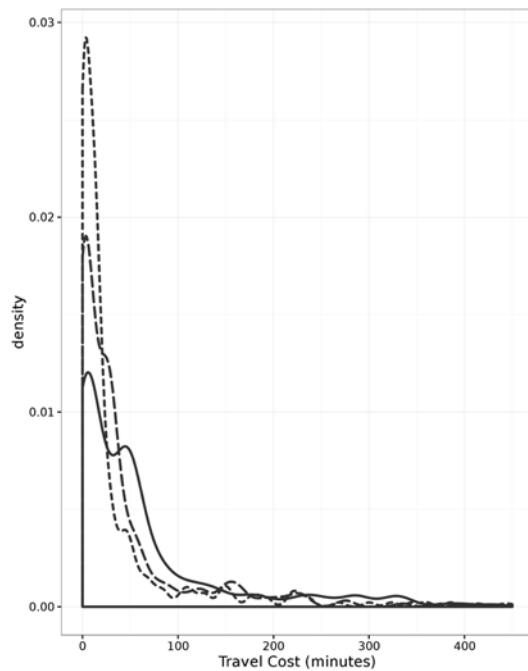


Data source: 2009 NHTS

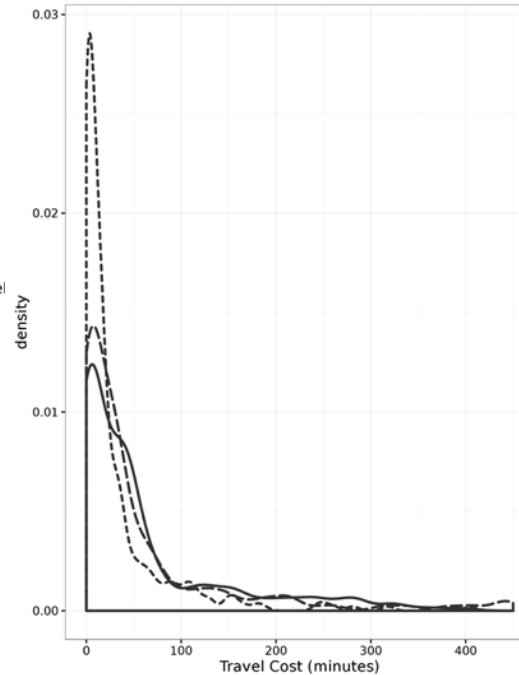
Transportation Costs by MSA (Low Income)



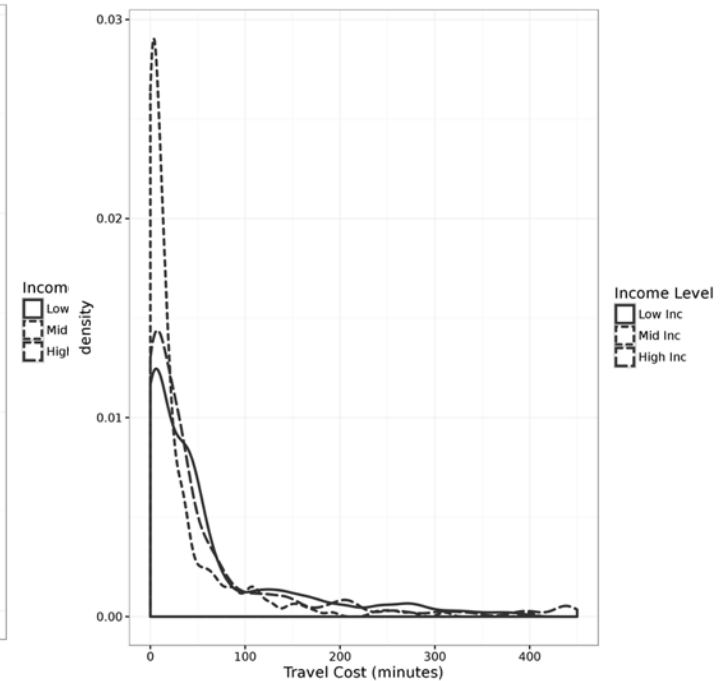
Generalized Costs by Income Level (Corvallis)



2010

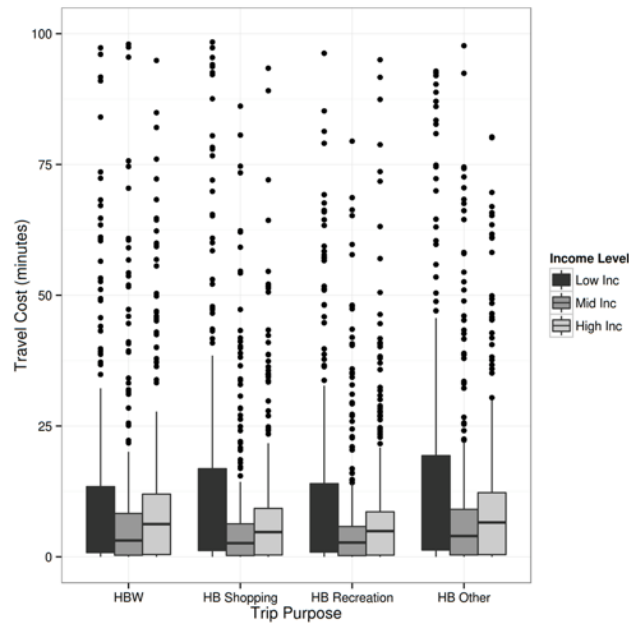


2030 Preferred

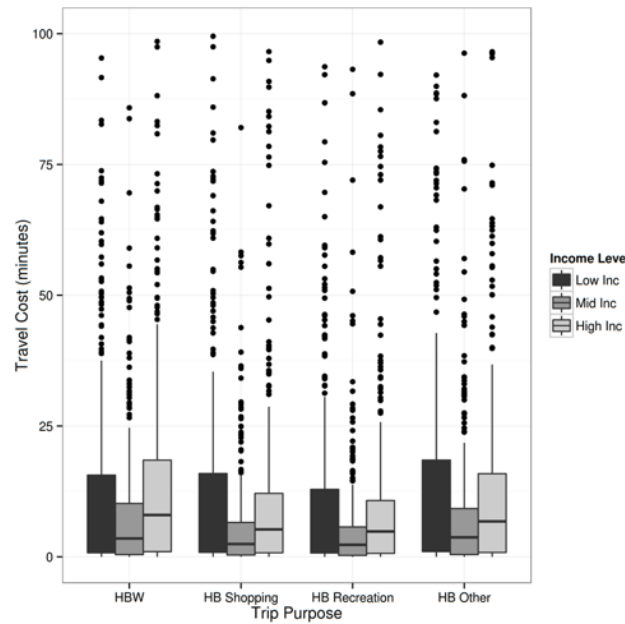


2030 Preferred Scen1

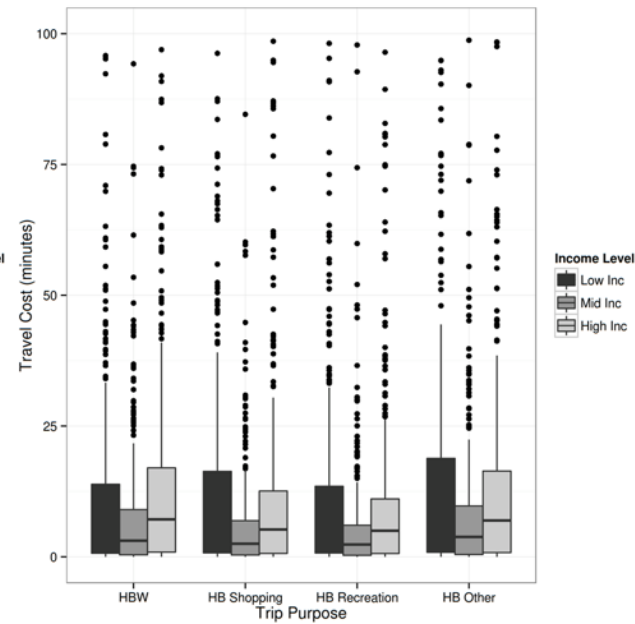
Generalized Costs by Trip Purpose and Income Level (Corvallis)



2010

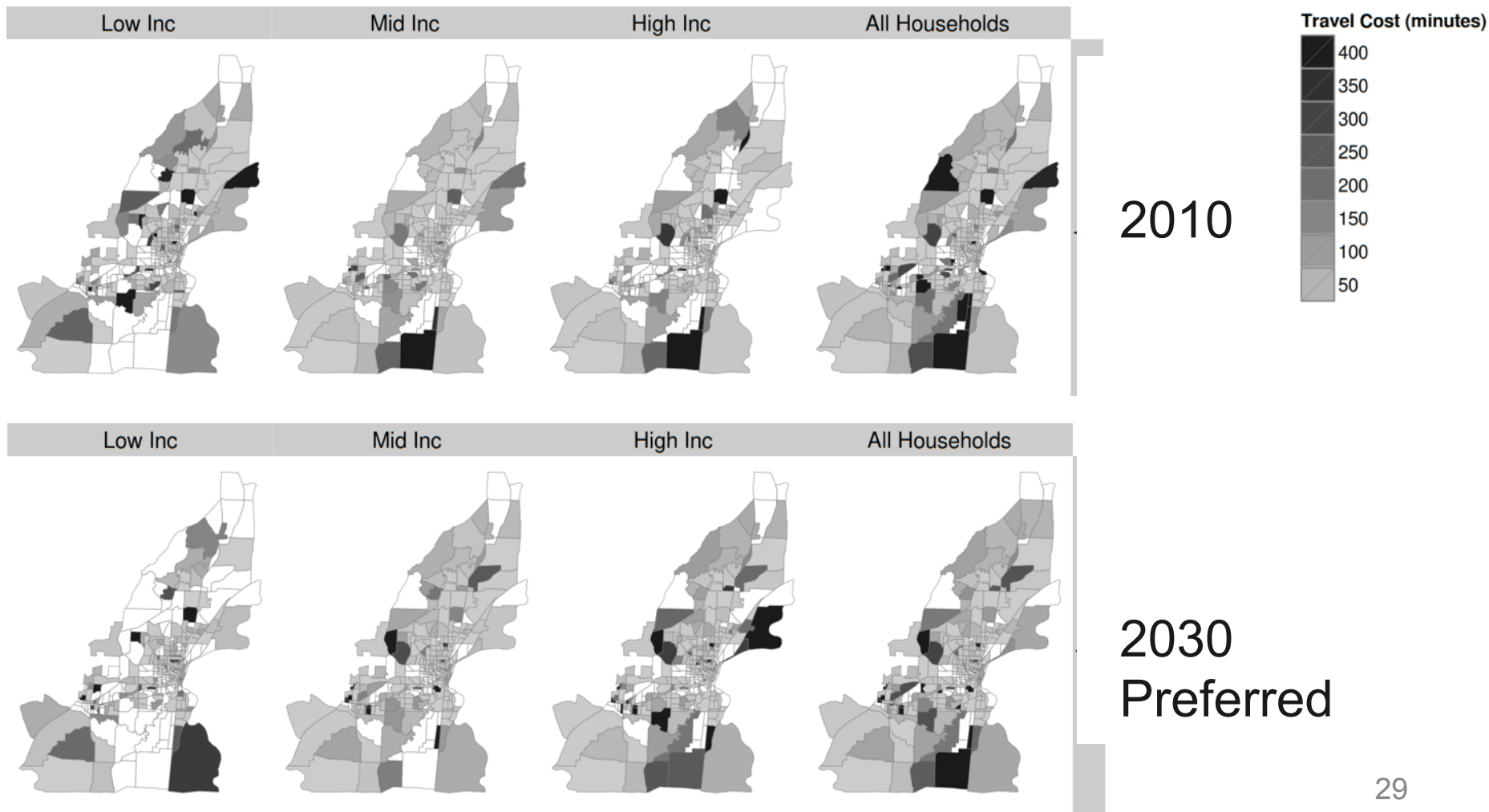


2030 Preferred



2030 Preferred Scen1

Generalized Costs by Income Level (Corvallis)



Ongoing and Future Work

- Adopted by the Accessibility Indicator Development Team (IDT) as one of indicators for the Oregon Mosaic project mandated by OJTA
- Test TCI usage in public engagement and policy making process
- Reconcile TCIs from the two methods;
- Verify patterns of transportation costs with information from alternative data sources, such as CES.

Code and Working Papers

- Code (under active development/testing) available at <http://github.com/cities-lab/tci>
- Working Papers:
 1. Wang, Liming, Bud Reiff, Brian Gregor, Huajie Yang, and Jenny Liu, 2015. Transportation Cost Index: A Comprehensive Multimodal Performance Measure of Transportation and Land Use Systems, presented at the 94th Annual Meeting of Transportation Research Board, Washington, DC, January 11-15, 2015.
 2. Wang, Liming, Huajie Yang and Jenny Liu, Transportation Cost Index as a Performance Measure for Transportation and Land Use Systems: New Approaches and Application in Portland, OR, presented at the 95th Annual Meeting of Transportation Research Board, Washington, DC, January 10-14, 2016.

Acknowledgements



National Institute for Transportation
and Communities



Oregon DOT

Extra Slides

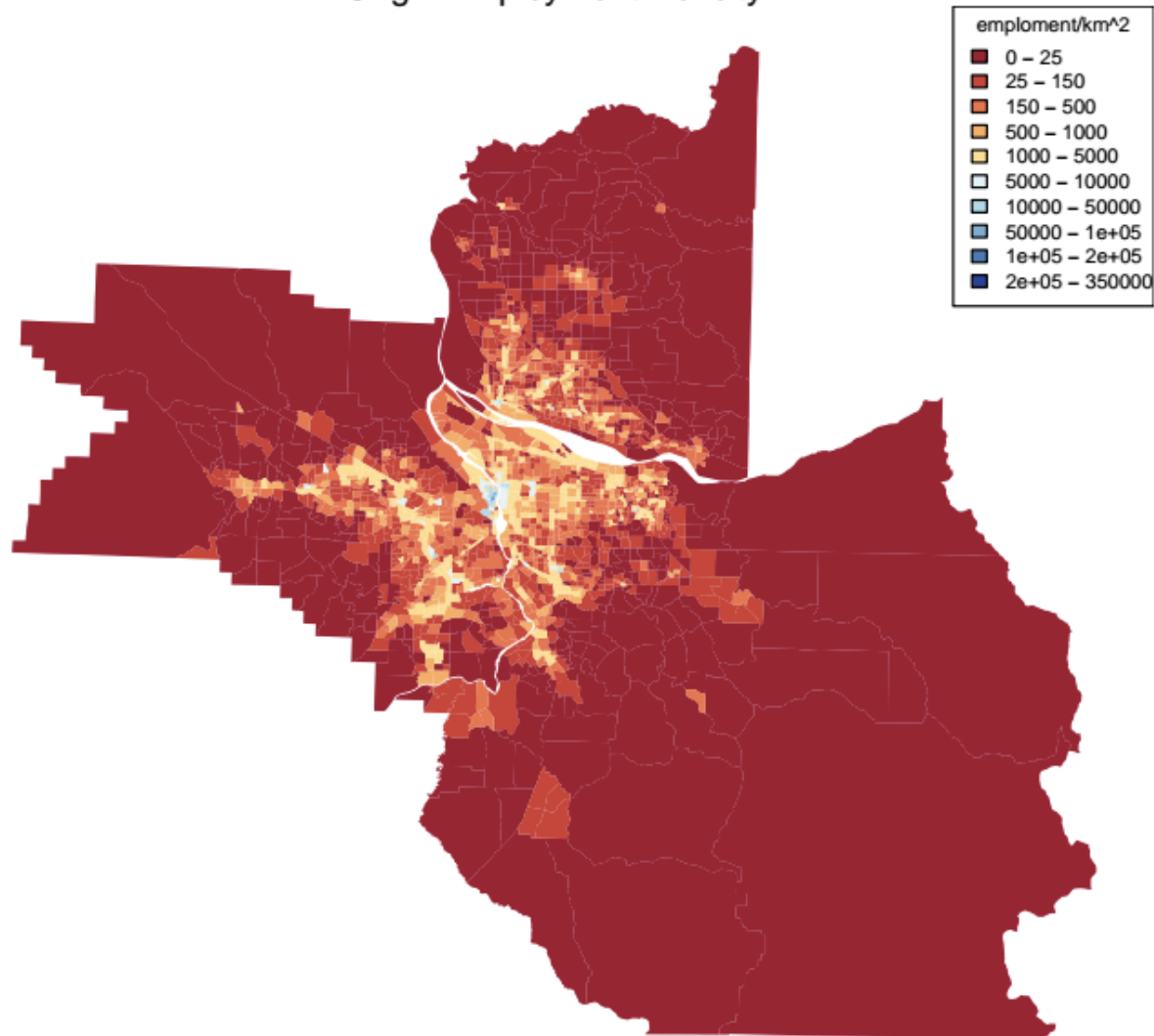
Income Levels

To be consistent with the classification used in Metro's TDM, household income levels are classified with this scale (1994 dollars):

- < \$25K: Low Income
- \$25-50K: Mid Income
- > \$50K: High Income

Identify Activity Centers (Travel Market Basket)

Origin Employment Density



Steps (Giulinao, 1991)

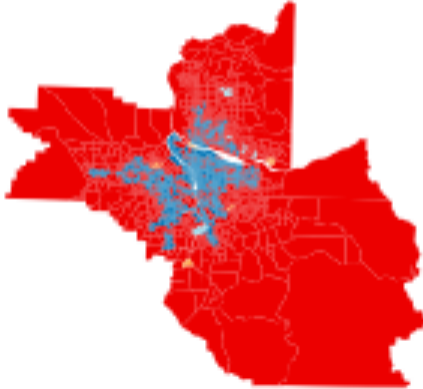
1. Calculate employment/size term density;
2. Identify TAZs with densities greater than density cutoff D and group contiguous TAZs identified into preliminary centers;
3. Calculate total employment or size terms for each center identified in step 2 and eliminate centers with total employment or size terms below total cutoff E from centers identified in step 2. The remaining are activity centers.

Determine Cutoffs

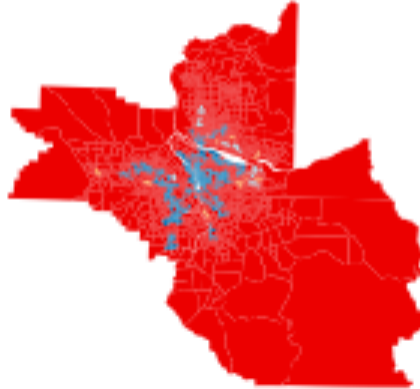
- Giulinao (1991) provides no guidance in selecting density cutoff (D) or total cutoff (E). They relied on expert knowledge
- Sensitivity Tests to determine cutoffs

Sensitivity Tests: HBW

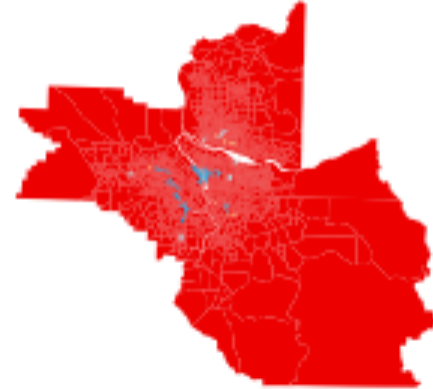
Density cutoff 50



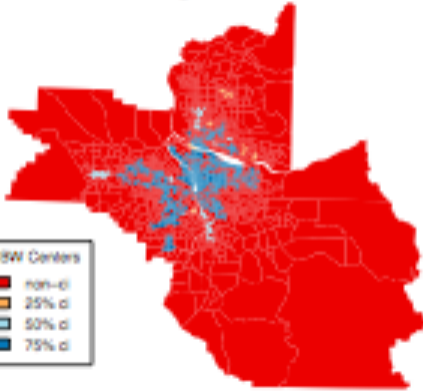
Density cutoff 70



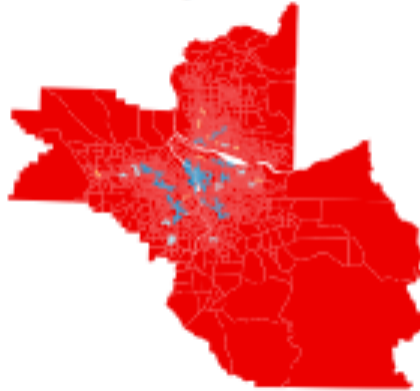
Density cutoff 90



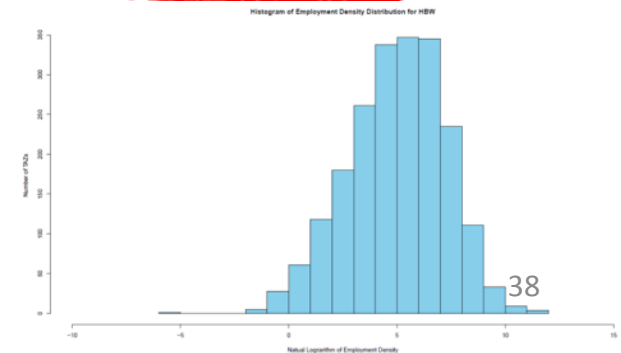
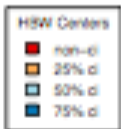
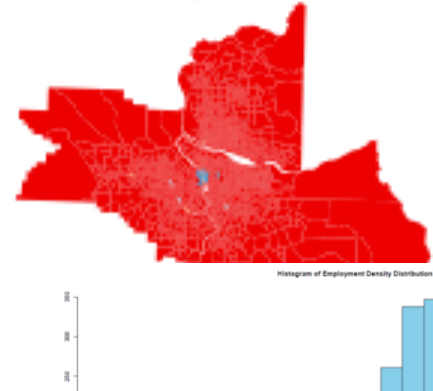
Density cutoff 60



Density cutoff 80

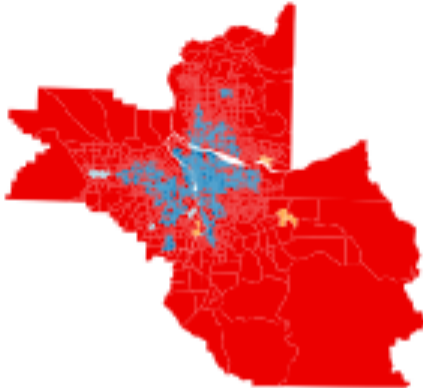


Density cutoff 95

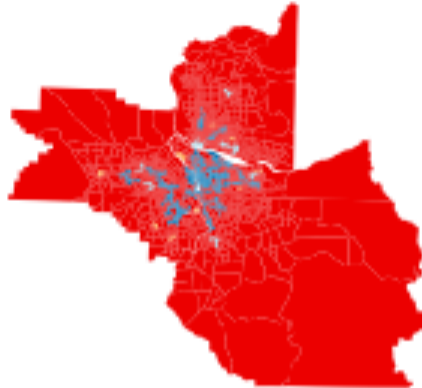


Sensitivity Tests: HBS

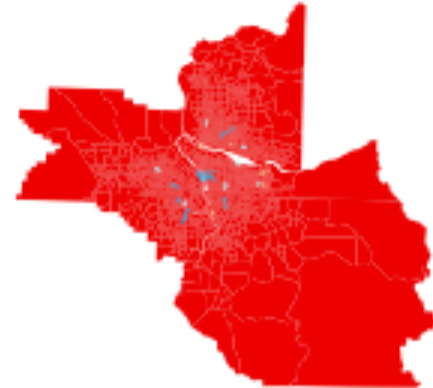
Density percentile 50



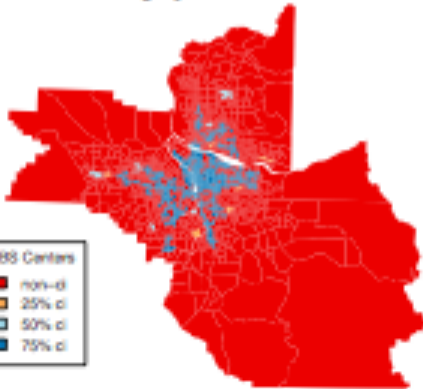
Density percentile 70



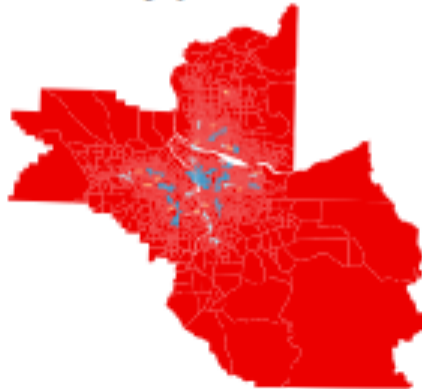
Density percentile 90



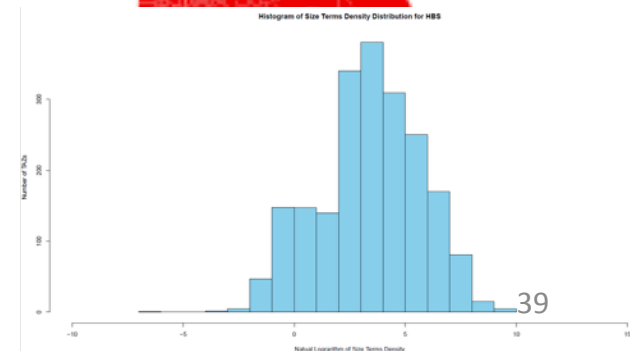
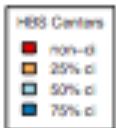
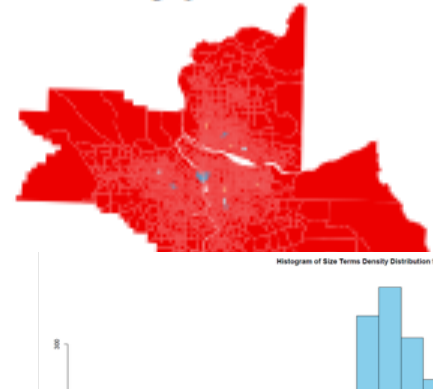
Density percentile 60



Density percentile 80

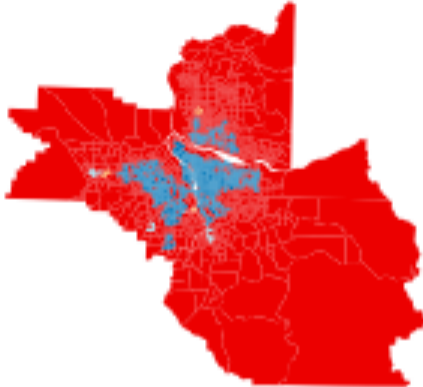


Density percentile 95

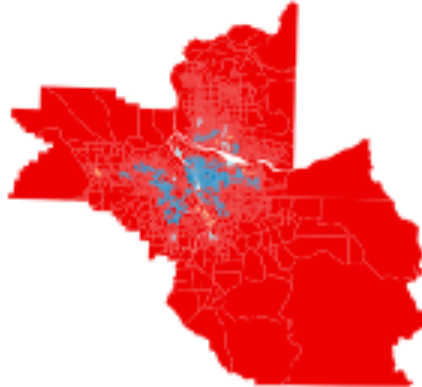


Sensitivity Tests: HBS

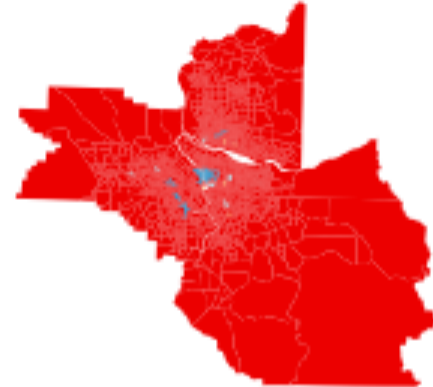
Density percentile 50



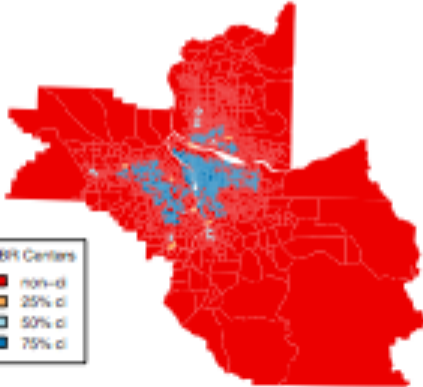
Density percentile 70



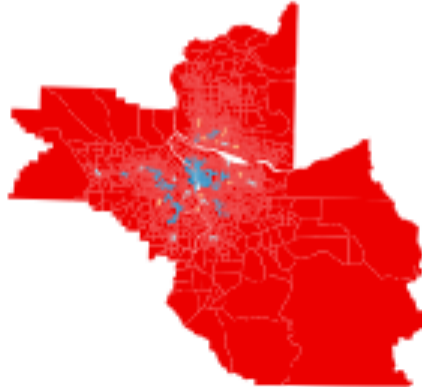
Density percentile 90



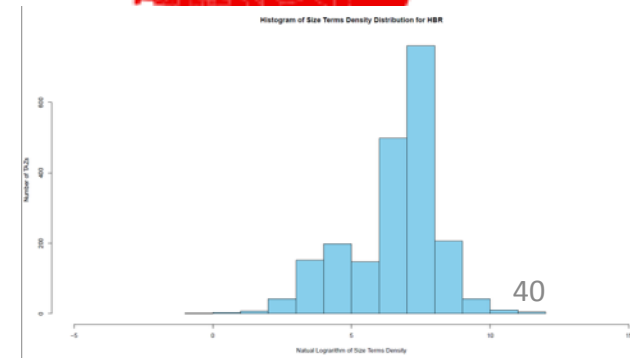
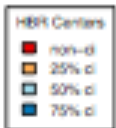
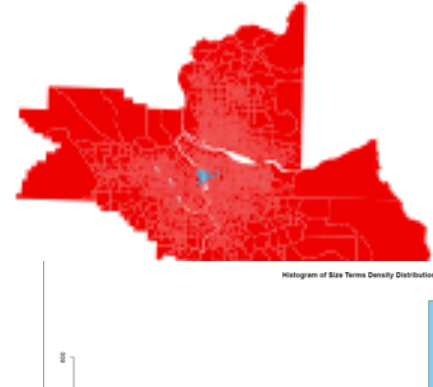
Density percentile 60



Density percentile 80

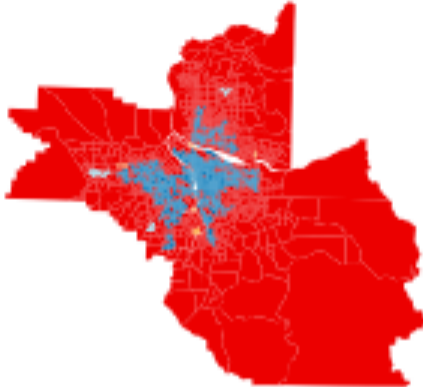


Density percentile 95

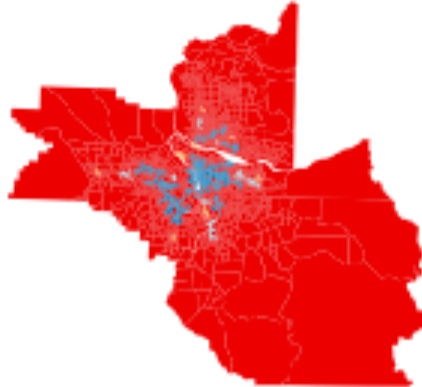


Sensitivity Tests: HBO

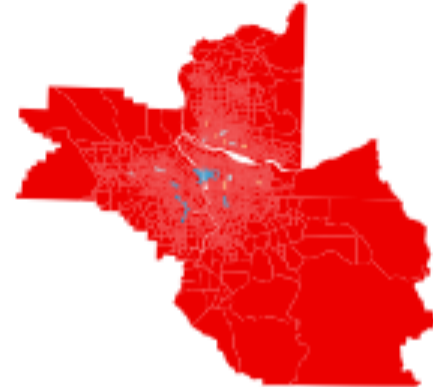
Density percentile 50



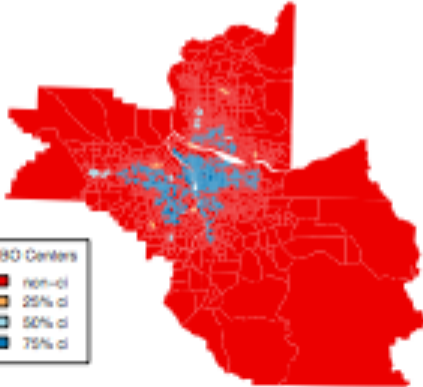
Density percentile 70



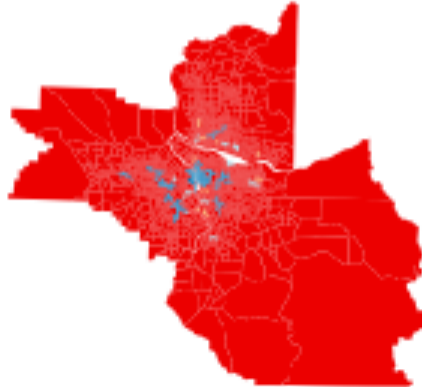
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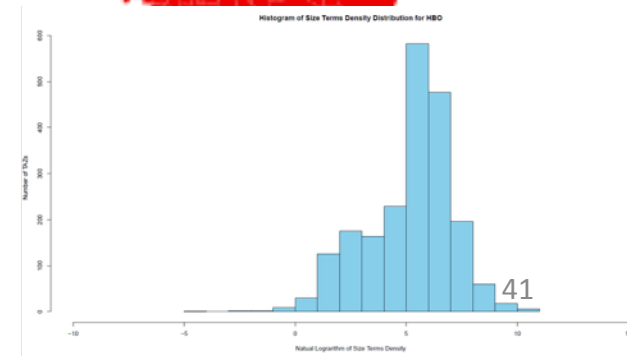
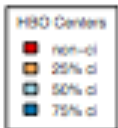
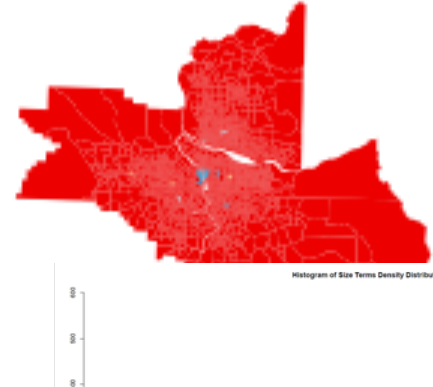
Density percentile 60



Density percentile 80



Density percentile 95



Travel Costs Calculation: Cost Estimate by Mode

- Auto

$$C_{auto} = C_{auto0} + k_{auto} \cdot TD_{auto} + w_{auto} \cdot TT_{auto}$$

- C_{m0} - Constant

- $k_{auto} \cdot TD_{auto}$ - Monetary costs (Fuel and tire costs, Ownership costs, insurance, etc) of driving

- $w_{auto} \cdot TT_{auto}$ - Time costs of driving

Travel Costs Calculation: Cost Estimate by Mode

- Public Transit:

$$C_{public} = \text{fare} + w_{public} \cdot TT_{public}$$

- Fare: Transit fares

- $w_m \cdot TT_{public}$: Time costs of riding transit

- Non-motorized modes (bicycling and walking)

$$C_{bicycle} = C_{bicycle0} + w_{bicycle} \cdot TT_{bicycle}$$

$$C_{walk} = w_{walk} \cdot TT_{walk}$$

- Time costs of Bicycling and Walking

Parameters

VOT (ratio to hourly wage):

walk=0.5 bike=0.5
auto / van/ truck driver=0.5
auto / van / truck passenger=0.35
bus=0.35 rail=0.35
dial-a-ride/paratransit=0.35
taxi=0.35 school bus=0.35
carpool / vanpool=0.35
other (specify)=0.5
driveAlone=0.5
drivePass=0.5
pass=0.35 busWalk=0.35
parkAndRideBus=0.35

Monetary costs per mile:

walk=0 bike=0
auto / van/ truck driver=\$0.592
auto / van / truck passenger=\$0.592
bus=\$1.01 rail=\$1.38
dial-a-ride/paratransit=0
taxi=\$2.6 school bus=0
carpool / vanpool=0
other (specify)=\$0.296
driveAlone=\$0.592
drivePass=\$0.592
pass=\$0.592 busWalk=\$1.01
parkAndRideBus=\$1.01